EFFECT OF SEEDS UPON HYDROGEN-ION CONCENTRATION OF SOLUTIONS[1]

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In the course of a study on the effect of single salt solutions with definite osmotic concentration values upon absorption by seeds[2], it was found that the H-ion concentrations of the solutions in which the seeds were immersed changed markedly during the process of imbibition. The general interest and importance of this phenomenon in connection with seed studies made its further investigation highly desirable. Accordingly single salt solutions of magnesium sulphate, sodium nitrate, calcium nitrate, sodium chloride, potassium chloride, and potassium carbonate were prepared, ranging in osmotic concentration values from 0.001 of an atmosphere to 7.0 atmospheres. The seeds used in connection with these solutions were corn, spring wheat, white lupine, watermelon, Canada field peas, Japanese buckwheat, dwarf Essex rape, and alfalfa. Fifty seeds of each of the larger kind and 100 each of alfalfa and rape were placed in small bottles each containing 100 cc. of solution. The bottles were placed on a laboratory table, and the seeds were allowed to soak for a period of fifteen hours, after which the solutions were poured off and the H-ion concentrations determined by the colorimetric method, using the double tube standards of GILLESPIE[3] and the apparatus devised by VAN ALSTINE.[4]

The results of these determinations are given in tables I and II in terms of P_H values. The initial P_H values of the solutions are here compared with the final values determined at the end of

[1] Paper no. 83 of the Journal Series, New Jersey Agricultural Experiment Station, Department of Plant Physiology.

[2] RUDOLFS, W., Effect of salt solutions having definite osmotic concentration values upon absorption by seeds. Soil Science **11**:277–293. 1921.

[3] GILLESPIE, L. J., Colorimetric determination of hydrogen-ion concentration without buffer mixtures, with especial reference to soils. Soil Science **9**:115–136. 1920.

[4] VAN ALSTINE, E., The determination of hydrogen-ion concentration by the colorimetric method and an apparatus for rapid and accurate work. Soil Science **10**:467–478. 1920.

TABLE I

INITIAL AND FINAL P_H VALUES OF SINGLE SALT SOLUTIONS IN WHICH SEEDS WERE SOAKED FOR FIFTEEN HOURS

P_H values	Atmospheres											
	7	6	5	4	3	2	1	0.5	0.1	0.01	0.001	0.00
$MgSo_4$												
Initial	6.5	6.5	6.4	6.4	6.3	6.3	6.2	6.2	6.1	6.0	6.0	6.0
After 15 hours: Corn	4.1	4.1	4.0	3.9	3.9	3.9	3.9	3.9	3.9	4.4	4.9	5.6
After 15 hours: Wheat	4.8	5.0	5.0	5.0	4.9	4.8	4.9	4.8	4.7	4.7	4.9	5.5
After 15 hours: Watermelon	4.9	5.0	5.0	5.0	5.0	5.0	5.0	4.9	4.8	5.1	5.8	5.8
After 15 hours: Peas	4.6	4.6	4.6	4.6	4.9	4.9	4.9	4.7	5.7	5.9	5.9	5.9
After 15 hours: Buckwheat	5.2	5.2	5.2	5.2	5.2	5.3	5.4	5.4	5.6	5.9	5.9	5.9
$NaNo_3$												
Initial	6.6	6.5	6.5	6.4	6.4	6.3	6.2	6.1	6.0	5.9	5.9	5.9
After 15 hours: Lupine	5.7	5.7	5.7	5.6	5.7	5.7	5.7	5.7	5.8	5.7	5.7	5.9
After 15 hours: Rape	5.5	5.5	5.6	5.5	5.5	5.7	5.7	5.7	5.7	5.8	5.8	5.8
After 15 hours: Alfalfa	5.5	5.5	5.5	5.5	5.5	5.5	5.5	5.5	5.7	5.7	5.7	5.8
After 15 hours: Corn	4.1	4.1	4.1	4.1	4.1	4.1	4.1	4.3	4.7	4.9	5.2	5.5
$Ca(No_3)_2$												
Initial	7.0	6.9	6.8	6.7	6.7	6.6	6.5	6.4	6.3	6.2	6.1	6.0
After 15 hours: Corn	4.2	4.2	4.2	4.2	4.1	4.1	4.1	4.1	4.5	5.5	5.5	5.9
After 15 hours: Lupine	5.5	5.5	5.6	5.6	5.6	4.9	4.9	4.8	5.2	5.6	5.5	5.8
After 15 hours: Peas	5.2	5.2	5.2	4.9	4.7	4.3	4.2	4.2	4.2	4.3	4.4	5.6
After 15 hours: Watermelon	4.2	4.1	4.1	4.1	4.1	4.1	4.1	4.1	4.2	4.9	5.1	6.0
NaCl												
Initial	6.6	6.5	6.4	6.4	6.4	6.3	6.3	6.2	6.2	6.1	5.9	6.0
After 15 hours: Corn	4.1	4.2	4.1	4.1	4.1	4.2	4.2	4.3	4.7	5.1	5.1	5.7
After 15 hours: Wheat	4.9	5.1	5.1	5.1	5.0	5.1	5.0	4.9	4.9	4.9	5.3	5.9
After 15 hours: Rape	4.1	3.9	4.1	3.9	3.8	4.0	3.7	3.9	3.9	4.1	4.1	5.9
KCl												
Initial	6.5	6.4	6.4	6.4	6.3	6.2	6.2	6.1	6.1	6.0	5.9	5.9
After 15 hours: Corn	4.1	4.1	4.1	4.1	4.1	4.1	4.2	4.3	4.7	5.0	5.1	5.9
After 15 hours: Wheat	5.9	5.7	5.7	5.7	5.7	5.7	5.7	5.7	5.6	5.8	5.8	5.8
After 15 hours: Lupine	5.7	5.7	5.6	5.7	5.7	5.7	5.8	5.9	5.9	5.9	5.9	5.9
After 15 hours: Peas	5.6	5.6	5.6	5.6	5.6	5.7	5.7	5.7	5.7	5.8	5.7	5.9
After 15 hours: Buckwheat	5.1	5.3	5.4	5.3	5.3	5.4	5.6	5.6	5.6	5.7	5.7	5.9
K_2Co_3												
Initial	+*	+	+	+	+	+	+	+	+	8.4	5.9	5.9
After 15 hours: Lupine	7.5	7.5	7.5	7.5	7.5	6.7	6.7	6.7	5.5	5.9	5.9	5.9
After 15 hours: Corn	+	+	+	+	+	9.6	9.2	8.7	6.5	5.8	5.7	5.7
After 15 hours: Rape	+	+	+	9.4	8.8	8.2	7.5	7.5	6.2	5.7	5.5	5.9

* + = higher than 9.8.

definite time intervals, during which the seeds remained in contact with the solutions. Each of the data given represents the average of the results obtained from two or more trials made with the same number of seeds soaked in equal amounts of solution for time periods of the same duration.

From the data of table I it will be observed that in all cases the H-ion concentrations of the solutions were markedly increased by contact with the seeds, even when strongly alkaline solutions of potassium carbonate were used. The seeds immersed in solutions of different concentrations of a single salt had a tendency to bring the P_H values of the solutions to a point which was fairly constant for a given species of seed, regardless of the original salt concentration or of the initial P_H values of the solutions, except when the solutions were very dilute. The maximum reaction change produced by corn in the various concentrations of all the salts used, except potassium carbonate, brought the final P_H values of the solutions to approximately 4.1, varying only slightly above or below this value except in the very dilute solutions (0.01 and 0.001 atm.) as previously noted. While the final P_H values produced by the seeds of other species were approximately constant in the different concentrations of the same salt, they varied considerably in the solutions of the different salts. For example, the final P_H values produced by wheat in the magnesium sulphate solutions were around 4.9, in the potassium chloride solutions they were approximately 5.7. Watermelon seeds produced corresponding P_H values of approximately 5.0 in the magnesium sulphate solutions and 4.1 in calcium nitrate solutions. Seeds of other species produced similar differences in the P_H values of the solutions of the different salts.

It will be observed that the initial H-ion concentration of the solutions of each salt increased slightly with the progressive decrease in the total salt concentration, but the P_H values of the solutions after soaking the seeds in them for fifteen hours showed a striking similarity in value, except in the very dilute solutions. With a few exceptions the seeds were incapable of bringing about any marked reaction changes in the very dilute solutions (0.01–0.001 atm.), behaving in these solutions in somewhat the same manner with respect to changes in reaction as they did in distilled water.

The effect of the seeds upon the H-ion concentration of the solutions in which they were immersed is strikingly shown in the case of the potassium carbonate solutions. The P_H values of these solutions were well above 9.8. After fifteen hours' immersion,

TABLE II

SEEDS IMMERSED IN $MgSO_4$ FOR DIFFERENT PERIODS, RINSED IN DISTILLED WATER, AND THEN PLACED IN FRESH SOLUTIONS CORRESPONDING TO THE OLD

P_H values	Atmospheres											
	7	6	5	4	3	2	1	0.5	0.1	0.01	0.001	0.00
	Corn											
Initial	6.5	6.5	6.4	6.4	6.3	6.3	6.2	6.2	6.1	6.1	6.0	6.0
After 3 hours	4.1	4.1	4.2	4.2	4.1	4.1	4.1	4.1	4.0	4.1	4.9	5.9
After 5 hours	4.2	4.2	4.2	4.2	4.1	4.1	4.1	4.1	4.0	4.1	5.1	5.9
After 8 hours	4.1	4.1	4.1	4.1	4.1	4.0	3.9	3.9	3.9	4.0	4.9	5.9
After 15 hours	4.1	4.1	4.0	3.9	3.9	3.9	3.9	3.9	3.9	4.1	4.9	5.9
After 18 hours	4.1	4.1	4.0	3.9	3.9	3.9	3.9	3.8	4.1	4.2	5.0	5.7
After 21 hours	4.1	4.1	3.9	3.9	3.9	3.9	3.9	3.9	3.9	4.1	4.9	5.6
	Rinsed and placed in fresh solution											
Initial	6.6	6.5	6.5	6.4	6.4	6.3	6.2	6.2	6.1	6.1	6.0	6.0
After 1 hour	4.3	4.2	4.1	4.1	4.2	4.1	4.1	4.1	4.1	4.2	4.9	5.9
After 21 hours	4.1	4.1	4.1	4.1	4.1	4.1	4.1	4.1	4.1	4.2	4.9	5.7
After 40 hours	4.1	4.0	4.0	4.1	4.0	4.0	4.0	4.0	4.0	4.2	4.9	5.7
	Buckwheat											
Initial	6.5	6.5	6.4	6.4	6.4	6.3	6.3	6.2	6.1	6.1	6.0	6.0
After 15 hours	5.2	5.3	5.2	5.3	5.2	5.3	5.4	5.4	5.6	5.9	5.9	5.9
After 21 hours	5.2	4.9	4.9	4.9	4.7	4.9	4.9	4.9	5.1	5.3	5.5	5.7
After 40 hours	5.3	5.6	5.2	5.4	5.1	5.1	5.3	5.4	5.3	5.5	5.7	5.8
	Rinsed and placed in fresh solution											
Initial	6.6	6.5	6.5	6.4	6.4	6.3	6.2	6.2	6.1	6.1	6.0	6.0
After 1 hour	5.1	4.9	4.9	5.0	4.9	4.9	4.9	4.9	4.9	5.1	5.5	5.9
After 5 hours	4.9	4.9	4.9	4.9	4.9	4.9	4.9	4.9	5.1	5.1	5.5	5.9
After 15 hours	5.0	5.0	5.1	5.0	5.0	5.0	5.1	5.0	5.0	5.5	5.5	5.8

lupine seeds brought the P_H values of these strongly alkaline solutions below the neutral point in concentrations below three atmospheres, and to 7.5 in all the higher concentrations. Both corn and rape seeds immersed in the solutions of low concentration of this salt also increased the H-ion concentration to such an extent as to bring the P_H values below the neutral point.

The maximum reaction change which the seeds were capable of bringing about in the small quantities of solution here used (100 cc.) was accomplished in a comparatively brief period of time, as is shown by the data in table II. Fifty corn seeds or fifty buckwheat seeds immersed in 100 cc. of magnesium sulphate solution, with osmotic concentration values of 7.0 atmospheres or less, produced the maximum reaction changes of which they were capable during an interval of one hour or less. The rate of reaction change of course is determined by the amount of solution used, total salt concentration, the number of immersed seeds, temperature, etc.

After the maximum reaction changes which the seeds were capable of bringing about in the solutions had been attained, the P_H values then remained approximately constant for an indefinite period. When the seeds were removed from the old solutions, rinsed with distilled water for a few seconds, and placed in fresh solutions with corresponding concentrations of the same salt, the phenomenon of reaction change again took place and continued until the maximum H-ion concentration was the same as that previously produced. The final P_H values with corn in magnesium sulphate solutions were 3.9 to 4.2, except in the very dilute solutions, always varying slightly on account of differences in temperature and other environmental factors. The seeds may thus be immersed several times successively in fresh solutions, the reaction changes taking place each time, but always bringing the final P_H values to approximately the same point, which is fairly definite for each species in the solutions of a given salt, until finally the absorptive capacity of the seeds is exhausted, and equilibrium is established between seeds and solution.

The exact cause or causes of the rapid reaction change of the solutions as indicated by changes in the P_H values has not been determined with absolute certainty. There are without doubt several contributing factors, but all the experimental evidence thus far produced appears to indicate that the primary factor, and the only one which could account for the rapid reaction changes in the single salt solutions here used, is that directly related to ion absorption by the seeds, the H-ion concentration increasing as the cations are removed from solution by absorption at a more rapid rate

than the anions. This is in accord with the work of PANTANELLI,[5] who concludes from his extensive researches that salt intake by the cells of living plants is an absorption phenomenon of single ions, and he attributes the reaction changes of solutions in contact with the roots of green plants to the fact that some ions are absorbed at a more rapid rate than others.

That the materials excreted by the seeds in contact with the solutions here used can have little influence in bringing about the rapid increase in H-ion concentration, is indicated by the fact that seeds immersed in distilled water, under conditions similar to those under which they were immersed in the single salt solutions, did not bring about any marked reaction changes, even when the seeds were in contact with the solutions during a period of forty hours. This is shown by the data in the last columns of tables I and II.

The rates at which these reaction changes take place and the factors influencing them, together with a study of salt solutions of a wider range and of a number of mineral and organic acids will be the subject of a later report.

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[5] PANTANELLI, E., Über Ionenaufnahme. Pringsheim's Jahrb. Wiss. Bot. **56**: 689–733. 1915.